Section VII. Use of Chemicals Only as an Alternative

A. Introduction to Chemical Control Methods

Under this Alternative, Ecology would permit aquatic herbicides that do not cause unreasonable adverse impacts, including prolonged water use restrictions.

This section updates the "Use of Chemicals Only" sections of the 1980 Aquatic Plant Management Environmental Impact Statement and its 1992 Supplement and adds new data on 2,4-D and endothall formulations Aquathol®, Aquathol® Super K and Hydrothol®191. This section will be further updated spring 2001 to include risk assessment information on diquat, triclopyr and copper compounds registered in Washington State. The current sections on diquat and copper have not been updated but will be when the risk assessments for those herbicides are completed. Triclopyr was not included in the original or supplemental EIS, so it will be a new addition to the 2001 SEIS.

Since new risk assessments are not planned for fluridone and glyphosate, changes in application practices and labeling since the 1992 SEIS have been noted and are reflected in this supplement where appropriate.

The information on each herbicide reviewed in this SEIS is brief, concise and not overly technical. Analysis and evaluation of the recently assessed compounds is based primarily on technical review found in the risk assessments supporting them and is simply summarized herein. Where the Final SEIS contains general information and conclusions, the detailed technical supporting information is referenced in the respective risk assessment appendix.

In response to requests by members of the Steering and Technical Advisory Committees, and as allowed by SEPA Rule WAC 197-11-430, the impact and mitigation information for each herbicide has been combined, rather than set in separate sections, to make this document more accessible for general guidance and reference. For purposes of uniformity, the herbicides reviewed in the 1992 SEIS that will not be updated at this time have been reorganized into the same format. However, the complete bibliographies for those herbicides are included at the end of the respective sections.

The supportive risk assessments found in the appendices follow the structural organization that the Environmental Protection Agency (EPA) Office of Pesticide Programs uses to develop data requirements for the registration of pesticides. They include basic data on the physical and chemical properties of each herbicide, the behavior of the compounds in the environment, and their toxicity to non-target organisms. These data contribute to the quantification of hazard. The suite of data developed in this manner have been evaluated under the use scenarios (the labeled directions for use) in order to determine exposure. Then, the risk assessment process combines the hazard and exposure data to determine the magnitude, if any, of risks for the use of the products when used according to the label. Where risks are identified, seasonal timing, rate or use limitations, or other criteria are suggested as possible risk mitigation criteria.

The herbicide reviews in this section are organized into:

- The registration status,
- The physical and chemical characteristics of the herbicide's active ingredients, and where relevant, the characteristics of the end use products,
- A review of potential environmental and human health impacts from exposure to the use of the compounds. This section combines the assessment of the effect data with the behavioral properties of the compounds in order to quantify risk for non-target organisms.

- The final part quantifies hazard or risk for the use of the products when used according to the label and proposes mitigation measures for each aquatic herbicide. Where risks are identified, seasonal timing, rate or use limitations, or other criteria are suggested as possible risk mitigation criteria, and
- A reference to the supporting appendix or a complete bibliography of citations is presented at the end of each herbicide review.

B. Types of Herbicides

Herbicides are selected for use based on impacts, availability, cost and effectiveness of control. Effectiveness of an aquatic herbicide is primarily dependent on its mode of action and suitability for the targeted aquatic plant. Aquatic plants are categorized as submerged, emergent or floating, indicating the way the plant typically grows. Plants growing only below the water line are submerged, those growing from below the water line to above the waterline are emergent, and those growing on the surface of the water, sometimes unrooted, are floating. Pre-emergent and post-emergent weed control refers to whether control measures are taken prior to or after germination of first growth of the plant. Herbicides used for aquatic weed control fall into one or more general categories:

- Contact herbicides are plant control agents that are used in direct contact with foliage and destroy only contacted portions of the plant.
- Systematic herbicides are applied to foliage and/or stems and are translocated to roots or other portions of the plant, resulting in death of the entire plant.
- Broad-spectrum herbicides kill most if not all plants with the appropriate dosage.
- Selective herbicides only kill certain plants or families of plants.
- Broadleaf herbicides generally kill dicot plants with broad leaves.

C. Registration Requirements

In order to register an aquatic herbicide for use with the EPA, the active ingredient and its formulations must be tested for toxicity birds, mammals and aquatic organisms, physical chemistry, environmental fate and effects on ground water. Additional work must be done to demonstrate expected magnitude of residue on edible products and residues in water. After these data are generated, they are submitted to EPA for review. If the reviews find that the product does not pose significant risk to humans, livestock, or wildlife and has a favorable environmental persistence and degradation profile, a registration will be granted. With that registration the manufacturer has permission to sell the product in the United States. However, each state may have its own separate registration process which may be more stringent than the EPA's registration process. Washington State's registration procedure follows EPA registration. It requires that the applicant submit a copy of the market label and a copy of the confidential statement of formula. Washington State Department of Agriculture reviews these submittals for compliance with state and Federal requirements. If these requirements are filled the product will usually be registered unless it presents an unusual hazard to the environment. A more detailed description of the registration process is given in the registration status sections of each herbicide appendix.

D. Tank Mixes, Inerts and Surfactants

In general, tank mixes are not permitted in the state of Washington for the control of aquatic weeds in public waterways. This is because risk assessment information is not available on mixtures of herbicides.

Ecology must approve the specific formulation as well as the active ingredient. "Inert materials" in a formulation may interact with the pesticide to give antagonistic, additive, cumulative or synergistic effects against target plants (aquatic weeds and algae) and non-target fish and aquatic invertebrates. For example, endothall acid is considerably more toxic to rainbow trout and bluegill sunfish when certain "inerts" are added, possibly due to a synergistic effect (Appendix D, Vol. 2, Sect. 4, p. 36).

If surfactants are used, care should be taken to use those registered for aquatic uses since they have potential toxicity to fish. Thickening agents like Polysar® or Nalquatic® are used in other states to control drift with liquid endothall products that are applied to floating weeds and may also allow subsurface applications to sink more deeply into the water column where they can be most effective. However, these two adjuvants are not registered for use in Washington State and therefore are not allowed for distribution here (Appendix D: Sect. 4, p. 36 and Personal Communication with Wendy Sue Wheeler, WSDA, May 30, 2000).

E. General Permit Conditions for Aquatic Herbicides

Several strategies are available for avoiding or minimizing potential impacts associated with use of aquatic herbicides. Some mitigation measures are applied generally to all proposed herbicide treatments because there are impacts common among various treatments while some are tailored to each specific proposal and/or herbicide proposed for use. The recommended mitigation in the following impact sections on herbicides supply most of the general and special conditions found in Ecology's Short-Term Modification Order (the permit boilerplate). Permit conditions are also supplemented by public notice procedures.

A few changes to the boilerplate language regarding notification have been made recently, based on the consensus of Ecology permit writers and headquarters staff (Ecology HQ, May 23, 2000). The changes generally add flexibility to timing requirements regarding notification without compromising intent of requirements. Copies of the Water Quality Modification Application, dated November 2000, and permit boilerplate, dated January 2001, are available in Appendix A.

F. 2, 4-D Aquatic Herbicide Formulations

1. Registration Status

One active ingredient of 2,4-D, 2,4-D butoxyethyl ester (BEE), is registered by WSDA for aquatic use in Washington State; however, another active ingredient, 2,4-D dimethlyamine salt (DMA) is available for aquatic weed control in lakes and ponds in other states. The 2,4-D DMA formulation, which comes in liquid form, has been found to be less toxic to aquatic biota in laboratory tests than the granular 2,4-D BEE formulation. Ecology is working with EPA and the manufacturers of 2,4-D DMA formulations to request a special local need registration for its use in Washington State.

2. Description

2,4-D (2,4-Dicholorophenoxy acetic acid) is the active component in a variety of systemic herbicide products used for both terrestrial and aquatic application sites. 2,4-D is a selective plant hormone type product that is translocated within the plant to the susceptible sites. Its mode of action is primarily as a stimulant of plant stem elongation. 2,4-D stimulates nucleic acid and protein synthesis and affects enzyme activity, respiration and cell division. It is absorbed by plant leaves, stems, and roots and moves throughout the plant, accumulating in growing tips. Its primary use is as a post-emergent herbicide.

2,4-D is formulated in a multitude of forms; however only two active ingredient forms are currently being supported by the manufacturers for use in aquatic sites. These are the dimethylamine salt and the butoxyethyl ester. The physical chemical characteristics and data reported in this assessment are limited to the pure acid active ingredient of these two formulations.

Dioxin Concern has been expressed over the association of 2,4-D products with low levels of chlorinated dioxins and furans. Extensive investigation by US manufacturers of technical grade 2,4-D has shown there are no halogenated dioxins and furans which exceed the limits of quantitation (LOQs) expressed in the June 15, 1987 USEPA Data Call-In Notice for dioxins and furans in 2,4-D products. There have been several reports of contamination of 2,4-D products produced outside the US (particularly in Russia), however, these products are not registered for use in the United States and therefore have no impact on the current discussion. Past concerns have been fueled by the finding of dioxins and furans in "Agent Orange", a mixture of 2,4-D and a related herbicide 2,4,5-T, which was used extensively in Vietnam. Subsequent work has shown that 2,4-D is not contaminated, but that the 2,4,5-T component was significantly contaminated, which has resulted in its being banned for use in the US.

Typical Use 2,4-D BEE is permitted for freshwater applications only; it is not permitted for marine applications. 2,4-D is a systemic, fast-acting, selective herbicide suitable for use, including spot-treatment use, on watermilfoil. Granular 2,4-D butoxyethyl ester (BEE) is a post-emergent systemic herbicide used primarily to control watermilfoil and water stargrass. In other states, liquid 2,4-D dimethylamine salt (DMA) is used primarily to control water hyacinth and water milfoil. Species other than those listed on the labels may also be controlled fully or in part by application of these products. However, the distributor makes no efficacy claims for control of weed species not listed on the label (Appendix C, Vol. 3, Sect. 1, p.8). The lower concentrations recommended on the label of the herbicide are often more effective at killing targeted aquatic plants than the higher concentrations allowed. Higher concentrations tend to "burn" the plant but not kill it. Lower concentrations are absorbed by the whole plant, resulting in a better kill. Typically, when used in aquatic applications, only 1 PPM is required for efficacy (Appendix C, Vol. 3, Sect. 2, p. 4).

2,4-D is not used as an algaecide because 2,4-D products are generally not toxic to indicator species of algae, with a possible exception of freshwater diatoms. 2,4-D products have a low toxicity to most blue-green algae even at high concentrations. There is some evidence that algae numbers increase when a water body is treated with 2,4-D for the control of watermilfoil due to the release of nitrogen and phosphate from decaying plants.

3. Environmental and Human Health Impacts and Mitigation Measures

This section describes anticipated impacts of using 2,4-D herbicide formulations to control freshwater aquatic plants on elements of the environment, aquatic biota and human health. When appropriate, mitigation measures are recommended and significant adverse impacts that cannot be mitigated are noted. A table summarizing recommended mitigation measures concludes this section. Detailed, technical supporting data and documentation for this section can be found in Appendix C, Vol. 3, 2-4-D.

Air

Inhalation Toxicity Little to no inhalation exposure is expected due to the methods of application. Acute inhalation overexposure to 2,4-D in animal studies have demonstrated signs of respiratory tract

irritation, e.g. salivation, lacrimation, mucoid nasal discharge, labored breathing, dried red or brown material around the eyes and nose. The signs did not persist beyond 3-7 days post exposure, nor were there any deaths (FAO, 1996). No signs of systemic toxicity following 2,4-D exposure have been reported in Washington State resulting from aquatic applications of 2,4-D.
Recommended Mitigation None beyond the label, applicators must follow all precautionary statements on specific herbicide labels for their own protection.

Earth

Soil Impacts from 2,4-D are not expected on soils unless an irrigation or flood incident occurs. Persistence of 2,4-D formulations are fairly short under conditions expected in most aerobic soils. Half-lives range from about 2 to 12 days with occasional longer times in isolated circumstances. Low accumulation and low leaching of 2,4-D are expected on soils receiving irrigation or floodwater due to effective degradation by microorganisms. At typical use rate concentrations, irrigation or flooding of crops with water that has been treated with 2,4-D DMA can cause damage to some crops and non-target wild plants. Although early growth stage damage has been observed on many crops including sugar beets, soybeans, sweet corn, dwarf corn and cotton, no significant reductions in yield were seen at harvest for most crops. Residue levels that would interfere with the marketability of crops were not seen in various crops including potatoes, grain sorghum, Romaine lettuce, onions, sugar beets, soybeans, sweet corn or dwarf corn. 2,4-D will not bioaccumulate in crop plants or fish at levels that will interfere with their marketability or consumption.

In general, there are no expected impacts to soils from the application of 2,4-D products to waterbodies in Washington State. Drift onto soils is not anticipated. Applications of granular formulations will typically be made from hand-held spreaders, spreaders mounted on boats or subsurface delivery systems. Liquid formulations (not currently permitted in Washington State) are generally applied subsurface.
Recommended Mitigation Aerial applications are not permitted in Washington State. Mixing and loading procedures found on herbicide labels must be followed to prevent spills on unprotected soils. However, in the event of a spill, spill response steps outlined in the water quality permit (General Condition G-5) from Ecology must be followed.

Soil Erosion Classical erosion effects typically do not occur. However, removal of plants from irrigation canals may result in erosive processes occurring to a limited extent.
Recommended Mitigation None beyond the label.

Sediment Aquatic applications of 2,4-D may result prolonged persistence of 2,4-D acid in sediments (half-lives of about 35 days) and adverse effects to benthic organisms, other aquatic biota and possibly humans. Treatment with the liquid 2,4-D DMA typically produces much lower concentrations of 2,4-D in the sediment than treatment with the granular 2,4-D BEE. Due to the extremely high toxicity of 2,4-D BEE, there is potential for adverse impact to the biota based on the results of laboratory studies.

Persistence in sediment is governed by temperature and dissolved oxygen content, which affect the ability of sediment microorganisms to break the 2,4-D molecule apart. The overall pattern is that 2,4-D BEE is rapidly broken down in natural pond and lake systems in a few days to 2,4-D acid, and the resulting acid is usually below detection levels (approximately 0.01 PPM) in treated area water within a month. In sediment, the acid may persist from a few weeks to as long as 3 months, with occasional instances of persistence to 6-9 months, though the latter is unusual. Longer sediment persistence is facilitated by the use of granular formulations that release 2,4-D BEE over a prolonged period.

Temperature has a pronounced effect on the rate of chemical reactions and metabolic processes. Willems *et al.* (1996), found degradation rates were quite similar at 10°C, 15°C, and 20°C in incubated sandy loam field soil, and that a major drop in degradation occurs at temperatures less than 7°C. In deeper lakes a thermocline can form during summer months wherein there is a sharp boundary between the warmer surface water and cold deeper water. Thermoclines can increase 2,4-D persistence in two ways. As there is little exchange of water across the thermocline, there is less water volume to dilute the herbicide, particularly in lakes treated over a large percentage of their surface. Any 2,4-D that penetrates the thermocline encounters a colder environment where degradation by microbes is slowed.

Sites that have never been exposed to 2,4-D products may degrade 2,4-D DMA, 2,4-D BEE and 2,4-D acid more slowly than sites that have a previous exposure history. It may take several weeks for bacteria capable of using 2,4-D as their sole carbon source to develop out of the lag-phase and rapidly degrade applied 2,4-D DMA or 2,4-D BEE. Such rapid degradation leads to a half-life in ponds and rice paddies of 1.5 to 6.5 days. However, if degradation, sorption and dilution factors are interacting in open waterways, the field dissipation half-life may be even shorter. Typical half-lives in Northwest waters are less than one week. Therefore, long-term persistence of 2,4-D BEE at concentrations that will cause environmental damage is not likely. Furthermore, since 2,4-D BEE has a low solubility and is rapidly hydrolyzed to the generally less toxic 2,4-D acid, the likelihood of 2,4-D BEE coming into significant contact with sensitive members of the biota is much reduced.
Recommended Mitigation: 2,4-D products should not be used when surface water temperatures less than 7° C (45°F) are anticipated at the time of application. Repeat applications where degradation may not have occurred can lead to concentrations of 2,4-D acid harmful to aquatic biota and should be limited.

Impacts to Benthic (bottom dwelling) Organisms: Liquid 2,4-D DMA (2,4-D dimethylamine salt) may adversely affect benthic organisms when applied at typical use rates in the field. While 80% of sediment invertebrates tested were not acutely affected by concentrations of 2,4-D DMA that exceed 100 mg a.i./L, the most sensitive species (glass shrimp and seed shrimp) exhibited high (LC50 = 0.15 mg a.i./L) to moderate (LC50 = 8.0 mg a.i./L) toxicity to 2,4-D DMA. Since the acute EEC (environmental effect concentration) is typically ~1.36 mg a.i./L (and can be as high as 4.8 mg a.i./L), the acute risk quotient (the ratio of exposure concentration divided by an effects concentration) is above the level of concern of 0.1 for the most sensitive benthic species tested. These calculations lead to the conclusion that the sediment biota may be at risk from acute exposure to 2,4-D DMA.

The chronic toxicity values are for 90% of the benthic biota (predicted chronic NOEC = 5.6, 27.5 and 0.0083 mg a.i./L for rainbow trout, *Daphnia magna* and glass shrimp, respectively). Therefore, the chronic risk quotient using an EEC of 0.091-mg a.i./L is less than the chronic level of concern of 1.0 for over 95% of the aquatic biota. The acute and chronic risk quotients do not exceed the level of concern for fish and free-swimming invertebrates (RQ = <0.016), therefore 2,4-D DMA can be used for control of aquatic weeds without significant impact to these segments of the biota. However, the sediment invertebrates may be at risk since the risk quotient for the most sensitive species exceeds the chronic level of concern of 1.0 (RQ = ~11).

2,4-D BEE toxicity is greater in regard to free-swimming invertebrates and safety to the biota. Since the highest bottom water concentrations that are likely to be encountered are 3.25 mg/L (Gallagher, 1992) and 2.0 mg/L (Shearer and Halter, 1980), there is a potential for benthic biota to be adversely affected by 2,4-D BEE. If benthic species like *Gammarus fasciatus, Gammarus lacustris*, brown shrimp, nymphal stoneflies, aquatic sowbug, chironomid midge, seed shrimp or glass shrimp encounter these concentrations of 2,4-D BEE immediately after application, the result could be fatal. However, Shearer and Halter (1980) state that "the toxic potential of 2,4-D BEE, as measured in the laboratory, is apparently not realized under the 2,4-D BEE concentrations and environmental conditions present during actual field use. The fairly rapid hydrolysis of 2,4-D BEE to 2,4-D acid in nature is probably a key factor responsible for this generally observed lack of environmental toxicity..."

Recommended Mitigation When available for use in Washington State, use DMA formulations of 2,4-D whenever possible rather than BEE formulations of 2,4-D because of its reduced toxicity to benthic organisms. Always use the lowest effective concentration to prevent acute toxicity. Apply 2,4-D BEE at concentrations ≤ 100lbs. /acre.

Water

Surface Water The overall pattern is that 2,4-D is rapidly broken down in natural pond and lake systems in a few days, while the resulting acid is usually below detection levels (approximately 0.01 PPM) in treated area water within a month.

BEE breaks down to 2,4-D acid in aquatic systems. The major degradates of the acid are 2,4-dichlorophenol (immediate) and CO_2 (final). Humic and fulvic acids bound to the sediment are also important degradates. Small amounts of dichloroanisole, 4-chlorophenol, and related compounds have also been reported. Much of the carbon in the 2,4-D molecule is taken up by soil microorganisms and used to build cell tissues or used in their metabolic processes like carbon from any other source. As is the case for soil, the minor products are likely intermediate compounds caught in a "snapshot" of the metabolic process. Liquid 2,4-D DMA formulations result in higher initial water concentrations than granular formulations, since all of the 2,4-D is applied directly to the water (Appendix C, Vol. 3, Sect. 3, pp.18-19).

Dilution could be the principle factor in dissipation of 2,4-D in water following spot treatments of aquatic systems. Spot treatments of Loon Lake, Washington resulted in rapid dissipation of 2,4-D residuals in the water column of treated areas. 2,4-D fell below detectable levels in the water column by 23 hours post treatment at one of the sites monitored, 48 hours at a second site and between 3 and 7 days at two other sites (Appendix D, Section 3.5.1.)

The trophic state of a natural water body exerts an indirect influence on 2,4-D persistence. In eutrophic lakes, with a high level of nutrients, microflora populations can be expected to be greater than in mesotrophic or oligotrophic lakes (medium to low nutrient concentrations). Therefore, a larger population of microflora, many of which can degrade 2,4-D, can be expected to be present and persistence would be expected to be shorter. Conversely, when a large pool of carbon is available from decaying plant and animal matter, 2,4-D may not be utilized by microorganisms as readily as in lower-trophic state lakes. Mesotrophic and especially eutrophic water bodies usually have a higher population of algae that can substantially contribute to the restoration of DO following an aquatic plant kill from a 2,4-D application as discussed above, and can thus help speed degradation by aerobic microflora such as *Arthrobacteria.*

One possible negative effect of a eutrophic state on 2,4-D persistence should be mentioned. As stated above, the high nutrient levels usually give rise to a dense population of algae and various macrophytes as well as phytoplankton and benthic organisms. In any lake, there is a continuous process of decay of a large number of dead organisms occurring, particularly on the lake bottom. In a eutrophic lake a proportionately larger amount of decaying organisms can be expected. The first stages of this decay are generally aerobic, which uses dissolved oxygen. If conditions occur such as poor water circulation, the formation of a thermocline, or a population crash of a dense species population, the bottom of the lake (and possibly shallower depths) can become anaerobic. The inhibiting effects of low DO on 2,4-D-degrading microorganisms then becomes a significant factor in the persistence of the compound (Appendix C, Vol. 3, Sect. 3, p.29).

Recommended Mitigation Repeat treatments shall be limited when conditions such as

- poor water circulation or,
- a population crash of a dense plant species population or
- a thermocline

causes the bottom of the lake (and possibly shallower depths) to become anaerobic, inhibiting the effects of 2,4-D-degrading microorganisms, a significant factor in the persistence of the compound.

Water Current Transport Another important physical process affecting 2,4-D persistence in larger water bodies is transport of treated water away from the treated area and replacement with untreated water through lateral circulation or vertical movement of water. In this regard, the larger the lake, the more wind blowing across the lake surface, and the more water exchange through inlet and outlet streams or rivers, the more likely it is that 2,4-D residues will be dispersed and diluted to below detection limits. In small lakes, detectable concentrations of 2,4-D may be carried a significant distance down an outlet stream if the flow is sufficient and degradation is slow. Vertical dispersion is the dominant mechanism of dilution in whole-treated lakes, while a combination of vertical and horizontal water movement contributes to dispersion and dilution in lakes treated over only a part of their surface. Both 2,4-D acid and endothall have high water solubility and are easily transported within water currents in a lake. If a large portion of the lake is treated, both 2,4-D and endothall can be carried out of a lake into outlet streams if water movement is rapid or if there are insufficient microflora to break the herbicide down quickly.
Recommended Mitigation To minimize potential impacts on river, or possibly, downstream estuarine biota, water mass movement and the specific water budget for a particular lake must be part of a application plan when applying to small lakes or for whole lake treatments.

Water Hardness Hardness affects the toxicity of 2,4-D. Hard waters, due to the presence of bicarbonate, have a tendency to be alkaline (basic) while soft water due to the presence of low bicarbonate levels has a tendency to be acidic. 2,4-D BEE is more toxic by 3 to 4-fold to salmonids in soft water than in hard water (Soft water LC50 = 0.4 to 1.1 mg/L; hard water LC50 = 1.1 to 4.3 mg/L). The 2,4-D BEE ester appears to be about 100-times more toxic to salmonids than the 2,4-D 2-EHE formulation (another commercial ester formulation of 2,4-D) and the 2,4-D-EHE formulation appears to be 3 to 20-times more toxic than the amine salt (2,4-D DMA).

In Washington State, hard waters with higher pH are generally found in Eastern Washington lakes relative to Western Washington lakes. 2,4-D BEE formulations appear to be more toxic to juvenile coho, pink salmon and rainbow trout in soft water environments. Therefore, 2,4-D BEE has greater potential for adverse impact in Western Washington lakes. The toxicity of 2,4-D DMA will be essentially unaffected since it is practically non-toxic to salmonids under both hard and soft water conditions (Appendix C, Vol. 3, Sect. 4. P. 35).
Recommended Mitigation Proposed treatment sites should be routinely tested for hardness prior to treatment with 2,4-D BEE formulations. A mitigation plan must be submitted prior to the application of 2,4-D BEE to lakes with soft water (15-20 mg/l as $CaCO_3$) if salmonids are present.

Water Chemistry Exposure of living plant tissue to 2,4-D products or other herbicides usually results in secondary effects that may impact the biota. When plants start to die, there is often a drop in the dissolved oxygen content associated with the decay of the dead and dying plant material. Reduction in dissolved oxygen concentration may result in aquatic animal mortality or a shift in dominant forms to those more tolerant of anaerobic conditions. There may also be changes in the levels of plant nutrients due to release of phosphate from the decaying plant tissue and anoxic hypolimnion. Also ammonia may be produced from the decay of dead and dying plant tissue and may reach levels toxic to the resident biota. Ammonia may be further oxidized to nitrite (which is also toxic to fish), and the almost nontoxic, nitrate. The presence of these nutrients may cause an alga bloom to occur. (Appendix C, Vol. 3, Sect. 3, p.30).

Recommended Mitigation Proposed whole lake treatments should have a plan to minimize adverse impacts from secondary effects of plant die-off and increased levels of nutrients in the lake water. Use buffer lanes as required by herbicide labels.

Groundwater. Ecology (1993) quotes Dynamac (1988) in reporting 2,4-D detection in about 100 of more than 1700 groundwater samples from nine states. The most likely routes for contamination are spills during mixing of application solutions at wellheads, illegal dumping, surface water runoff from treated fields, and movement down through the soils from heavily treated agricultural land. With respect to groundwater movement, the difference between terrestrial uses of 2,4-D and aquatic weed control uses is that lakes provide, in essence, an isolated incubator in which 2,4-D degradation can take place without immediate impact on surrounding soil (Appendix C, Vol. 3, Sect. 3, p.47).

In some situations, 2,4-D has been seen in ground water where recharge areas have been treated with 2,4-D BEE. These recharge areas usually had porous bottoms (sand or gravel) with clay layers located below the bottom of the well shaft.
Recommended Mitigation Groundwater must be tested prior to treatment where herbicide contamination has been documented. Washington groundwater maximum criteria for 2,4-D is 0.10 mg/l (Chapter 173-200 WAC). Contaminated sites cannot be re-exposed to 2,4-D without an approved vegetation management plan that assures protection of groundwater.

Public Water Supplies Some labels warn that products are not to be applied to waters used for irrigation, agricultural sprays, watering dairy animals or domestic water supplies. Some restrict treatments within one-half mile of potable water intakes. All applications must adhere to label restrictions. However, risk assessment results of chronic exposure assessments indicate that human health should not be adversely impacted from 2,4-D exposure via ingestion of fish, ingestion of surface water, incidental ingestion of sediments, dermal contact with sediments, or dermal contact with water (Appendix C, Vol. 3, Sect. 5, p.46).
Recommended Mitigation: Label conditions apply. If water withdrawals exist within one-half mile of the proposed treatment area, an approved mitigation plan must be submitted prior to treatment. Monitoring flows at all outlets may be required by the permit manager. Restrictions must be in effect until herbicide levels are at or below the drinking water limit of 0.1 mg/L (Title 246-290-310(7)(ii) WAC). If outflows of treated water are anticipated, outlets must be blocked until herbicide levels are at or below the drinking water limit of 0.1 mg/L (Title 246-290-310(7)(ii) WAC).

Wetlands The upstream presence of 2,4-D products at concentrations effective against plants may adversely affect non-target wetland biota. Destruction of aquatic plants may be detrimental to a number of fish species as well as amphibians, reptiles, insects and birds. Some of the most susceptible species of invertebrates are estuarine species including grass shrimp, glass shrimp, and seed shrimp. The estuarine crab (*Uca uruguayensis*) has been eliminated from some estuarine areas due to the effects of 2,4-D. It is unclear if this is due to an avoidance response or an acute or chronic toxicity response. The presence of estuarine crabs and estuarine shrimp like those mentioned above are critical since they are important to the maintenance of the food web that attracts many species of fish. Anaerobic sediment typically found in estuaries can lead to the production of 2,4-chlorophenol or 4-chorolpehnol which are both very toxic to some species of aquatic macrophytes, marine phaeophytes, various beneficial fungal species and amphipods (Appendix C, Vol. 3, Sect. 4, p. 102). Also Wetland Mitigation for All Methods pages 11-14.
Recommended Mitigation Water quality in non-target wetlands shall be maintained and protected unless it can be shown that the impact is unavoidable and necessary. Avoidance shall be the primary means to achieve the water quality goals. When it has been determined that lowering the water quality of a wetland is unavoidable and necessary and has been minimized to the maximum extent practicable, wetland losses and degradation shall be offset, where appropriate and practicable, through deliberate restoration, creation, or enhancement of wetlands.

- In-kind replacement of functional values shall be provided, unless it is found that in-kind replacement is not feasible or practical due to the characteristics of the existing wetland and a greater benefit can be demonstrated by an alternative. In such cases, substitute resources of equal or greater ecological value shall be provided.
- On-site replacement shall be provided, unless it is found that on-site replacement is not feasible or practical due to physical features of the property or a greater benefit can be demonstrated by using an alternative site. In such cases, replacement shall occur within the same watershed and proximity.
- A mitigation plan shall be required for proposed mitigation projects. Elements that may be required in a mitigation plan include:
    a. A description of the impact or damage that is being mitigated.
    b. A description of the mitigation site,
    c. A discussion of the goals of the mitigation, e.g., restoring a native plant community, enhancing the wildlife habitat values by diversifying vegetation, replacing native aquatic vertebrates, etc.

Plants

Algae For the most part, 2,4-D products are not toxic to indicator species of algae, particularly 2,4-D DMA and 2,4-D acid. An exception may be freshwater and saltwater diatoms. 2,4-D products have a low toxicity to most blue-green algae at higher concentrations. There is some evidence that algae numbers increase when a water body is treated with 2,4-D DMA or 2,4-D acid for the control of Eurasian watermilfoil due to the release of nitrogen and phosphate. The phytoplankton cell count may double within a few days or weeks of treatment with 2,4-D. There may also be shifts in dominant species to those which find water temperatures and nutrient concentrations that occur after milfoil lysis ideal for growth (Appendix C, Vol. 3, Sect. 4, p. 5).
Recommended Mitigation Use only on plants specified on the label. Not for use on algae.

Plant Selectivity 2,4-D can be extremely selective or non-selective depending on conditions in the water body. However, the labeled used for 2,4-D BEE and 2,4-D DMA in aquatic ecosystems is limited. 2,4-D is used primarily for the control of *Myriophyllum spicatum* (Eurasian watermilfoil). However, it also has utility in the control of other species, i.e. *Myriophyllum spp., Heteranthera dubia* (water stargrass) at 100 to 200 Kg product/ha and *Utricularia spp.* (bladderwort), *Nymphaea spp.* (fragrant water lily), *Nuphar spp.* (yellow water lily), *Brasenia spp.* (watershield), *Trapa natans* (water chestnut) and *Ceratophyllum demersum* (coontail) at 150 to 200 Kg product/Ha. The use of 2,4-D BEE at 100 Kg product/ha can eliminate Eurasian watermilfoil within 3 to 6 weeks after application. Native (Wisconsin) plant species like *Ceratophyllum spp.* (coontail*), Elodea canadensis* (American waterweed) and, *Potamogeton crispus* (curly-leaf pondweed*), P. zosteriformis* (flat-stem pondweed), muskgrass, *Najas spp.* (naiads), *M. sibericum* (northern watermilfoil), *M. heterophyllum* (variable leaf milfoil), *Rununculus spp.* (water crowfoot), *H. dubia* (water stargrass) white-stem pondweed and water celery also declined within the first five weeks after treatment in early spring. However, 80 to 120 percent of the pretreatment standing crop returned by late August. Eurasian watermilfoil remained at low levels of dominance (3%-5%) of the area cover for two years after treatment (Table 16 (Helsel, 1996)). The amine salt of 2,4-D was used in a manner similar to 2,4-D DMA to control *Eichornia crassipes* (waterhyacinth) and *Myriophyllum aquaticum* (parrotsfeather) in Portugal. The application rate was 6.48 Kg a.i./ha (1.6 mg/L 2,4-D at zero hour). Control of parrotsfeather often contributed to the spread of other undesirable species like *Sparangium erectum*, *Typha spp.* and *Paspalum pasapalodes*. The aquatic macrophytes, currently of greatest concern in the Northern Tier of States (including Washington), are *Myriophyllum spicatum* (Eurasian watermilfoil), *Potamogeton crispus* (curly-leaf pondweed), *Egeria densa spp.* (Brazilian elodea), *Monoesius hydrilla, Spartina alterniflora* (smooth cordgrass), *Lythrum salicaria* (purple loosestrife), *Phragmites australis* (common reed), *Nuphar spp.* and *Nymphaea spp.* (water lilies) and *Trapa natans* (water chestnut). Of these, only Eurasian watermilfoil, purple loosestrife, water lilies and water chestnut are effectively controlled with a 2,4-D product. 2,4 D BEE and 2,4-D DMA are effective against Eurasian watermilfoil, and water chestnut (Robinette, 1998-1999 and Westerdahl et al., 1988 and Getsinger, 2000 personal communications).

Treatment of a demonstration plot at Loon Lake, Washington with 2,4-D BEE at 100 lbs./acre resulted in the effective suppression (87%) of Eurasian watermilfoil for one year after treatment. However, other indigenous plant species were not reduced in biomass or frequency due to the affects of 2,4-D treatment. The plants that appeared to be unaffected by treatment with 2,4-D BEE included: American waterweed, several species of pondweed (*Potamogeton spp.*), naiads, water stargrass, and *Chara spp.* Although *Megalodonta beckii* and *Vallisneria Americana* appeared to slightly stimulated in growth by 2,4-D, these effects were considered by the authors to be seasonal and unrelated to the use of 2,4-D BEE (Parsons et al, 1999 in press).

The differences in the scenarios for these results were as follows: 1) The Beulah Lake, Wisconsin applications were to coves which had been isolated from the main body of the lake by polyvinylchloride curtains. This allowed for little water exchange and resulted in increased exposure times. 2) The Loon Lake applications were made to an open water body that allowed for extensive mixing and dissipation leading to decreased exposure times. Getsinger and Westerdahl (1986) and Sprecher et al (1998) previously found that both exposure time and treatment rate have a strong influence on the degree of damage due to treatment with 2,4-D.
Recommended Mitigation Use as directed by the label.

Food Chain 2,4-D BEE has a tendency to accumulate in sediment and plants from 1-7 days (Gangstad, 1986). This may be a reflection of plants and sediments "metabolizing" 2,4-D to products that can be incorporated into the plant structure or the sediment (as humus). Animals, however, rapidly hydrolyze adsorbed 2,4-D BEE to 2,4-D acid and excrete it unchanged back into the water. 2,4-D should not bioaccumulate; it should be rapidly eliminated from any organisms that ingest it; and it should not bioaccumulate as it passes up the food chain.

Eurasian watermilfoil apparently bioconcentrates 2,4-D to levels 33 to 94-fold higher than the levels found in water, but eliminates this material within 16-weeks after the watermilfoil mass has undergone extensive decay. The release of 2,4-D from decaying watermilfoil probably has little effect on the concentration of 2,4-D in water since the highest concentration in plants is only about one percent of the total 2,4-D in the aquatic system (Appendix C, Vol. 3, Sect. 4, p. 30).
Recommended Mitigation: None beyond the label.

Rare and "Sensitive" Plants 2,4-D is normally applied as a granule (2,4-D BEE) at or below the water surface. Thus accidental exposure to shoreline vegetation during application will be minimal.
Recommended Mitigation If any proposed "sensitive" plants or candidate species under review for possible inclusion in the federal or state list of endangered or threatened species exist in or near the area to be treated with 2,4-D products, the applicator must leave a protective buffer zone between the treated area and the species of concern (Appendix C, Vol. 3, Sect. 4, p.61). Check for plant listings at http://www.wa.gov/dnr/htdocs/fr/nhp/wanhp.html .

Non-targeted Plants 2,4-D is a systemic, fast acting, selective herbicide suitable for use on Eurasian watermilfoil. When used at concentrations to treat milfoil, it often does not impact native plants.
Recommended Mitigation Use only on plants specified on the label. Consult the label for specific restrictions on plant applications.

Animals

Bioconcentration in animals is not likely for 2,4-D DMA, 2,4-D BEE or their hydrolysis/dissociation product (2,4-D acid). Although short term bioaccumulation of 2,4-D BEE can be fairly high in fish, after three hours of exposure 2,4-D BEE is converted to 2,4-D acid and excreted. If fish are "fed" 2,4-D acid, >90% is excreted within 24 hours. Work conducted in the field tends to corroborate this data since it was found that fish have little tendency to bioconcentrate 2,4-D and any that does is rapidly eliminated.
Recommended Mitigation None beyond the label.

Habitat Initial elimination of excessive exotic aquatic plants may increase habitat for fish (Bain & Boltz, 1992). Growth and reproduction of fish may be more due to general metabolic stimulation of benthic microorganisms and subsequent greater availability of fish food stock than a precise control of the amount of habitat available (Appendix C, Vol. 3, Sect. 4, p. 61).
Recommended Mitigation WDFW requires that contiguous areas of native vegetation covering a minimum twenty-five (25) to forty (40) percent of the littoral area be left intact. When treating large areas, random strips or patches of native aquatic vegetation must be left untreated for fish habitat use. At least twenty-five (25) to forty (40) percent of the native submerged vegetative cover must be retained for optimum cover and forage for fish and wildlife.

Aquatic Biota 2,4-D BEE may have significant acute or chronic impacts on animal biota when applied at rates recommended on the label. Laboratory data indicate that 2,4-D BEE is toxic to fish, free-swimming invertebrates and benthic invertebrates; data also indicate that toxic potential is not realized under typical concentrations and conditions found in the field. This lack of field toxicity is likely due to the low solubility of 2,4-D BEE and its hydrolysis to the practically non-toxic 2,4-D acid (Appendix C, Vol. 3, Sect. 4, p. 11).
Recommended Mitigation None beyond the label.

Fish 2,4-D BEE, has a high acute toxicity to fish (rainbow trout fry and fathead minnow fingerlings) under laboratory conditions. Formal risk assessments indicate that short-term exposure to 2,4-D BEE can cause adverse impacts to fish. 2,4-D acid has a toxicity similar to 2,4-D DMA for the common carp, cutthroat alvins and rainbow trout.

Limited field data with sentinel organisms (caged fish) and net capture population surveys indicate that 2,4-D BEE lacks acute environmental toxicity to fish when applied at labeled rates. However, research indicates that the smoltification process of several species of salmon is affected differently by the exposure to sub-lethal concentrations of DMA and BEE formulations of 2,4-D. For example, smolting coho salmon survive exposure and seawater challenges after exposure to up to *200 mg/L* of 2,4-D DMA while smolting coho, pink or sockeye salmon exposed to *1 mg/L* of 2,4-D BEE for 24 hours survived subsequent seawater challenge tests for at least 96 hours (Appendix C, Vol.3,Sect.1, p.8). Several species of fish including sheepshead minnow and mosquito fish are known to avoid 2,4-D BEE at concentrations typically found in the field.

All anadromous fish undergo smoltification and are susceptible to stress during this life stage. In addition, cutthroat trout's early life stages (yolk-sac, fry) have been shown to impacted by 2,4-D esters. Woodward and Mayer (1978) noted a significant reduction in survival of cutthroat alevins when they were exposed to 2,4-D BEE.

The current Navigate® (2,4-D BEE) label rates for milfoil are 100 lbs./acre and 200 lbs./acre, which equate to 27.6 to 55.2 lbs./active ingredient/acre. Using the low rate of 100 lbs./acre equates to 3.4 PPM at depths of 3 feet and 1.3 PPM at depths of 8 feet (PPM concentrations are approximately equivalent to mg/L concentrations). The high rate of use (200 lbs./acre) equates to 2.6 PPM at 8 feet depths and 2.0 PPM at 10 feet depths.

2,4-D BEE is moderately toxic to free-swimming daphnia and highly to moderately toxic to most benthic invertebrates. However, the low solubility of 2,4-D BEE and hydrolysis to 2,4-D acid would tend to limit exposure to the much less toxic 2,4-D acid. 2,4-D acid has a toxicity similar to 2,4-D DMA for most species of invertebrates. For free-swimming invertebrates, 2,4-D acid and its sodium salt is practically non-toxic. (Append. C, Vol. 3, Sect. 4, p. 9).
Recommended Mitigation Exposure to salmonids at all life stages must be avoided. When treatments are unavoidable due to infestations of noxious aquatic weeds that compromise designated uses of a waterbody (as specified under WAC 173-201A-030(5) or WAC 173-201A-120(1) when revised) applicants should use the lowest effective concentration. Apply BEE at concentrations ≤ 100lbs. /acre. If endangered species are present, WDFW must sign off on the application prior to treatment. Follow label restrictions for oxygen ratios.

Amphibians Acute data for 2,4-D DMA salt and 2,4-D acid are available for several species of amphibians (the frog *Limondynastes peroni,* Indian toad *Bufo melanostictus* and the Leopard frog). The data indicate that 2,4-D DMA is relatively non-toxic to amphibians while 2,4-D acid is relatively non-toxic to the Leopard frog (*Rana Pipiens*) and moderately toxic to the Indian toad. Although these data are limited to only a few studies it appears that 2,4-D acid may be more toxic in these species than 2,4-D DMA (Appendix C, Vol. 3, Sect. 4, p. 99).
Recommended Mitigation When available, use DMA formulations of 2,4-D. When treatments are unavoidable due to infestations of exotic aquatic weeds, applicants should use the lowest effective concentration. Follow-up methods should be used to minimize the need for repeat applications.

Birds Acute oral data for 2,4-D acid and 2,4-D BEE are available for several different species of birds (See Table 30: Appendix C, Vol. 3, Sect. 4, p. 193). These data indicate that the 2,4-D acid is moderately toxic to practically nontoxic to birds when orally dosed and that 2,4-D BEE is practically nontoxic to birds when orally dosed. Although 2,4-D BEE and 2,4-D acid do not pose significant risks to terrestrial wildlife, the following measures should be considered prior to all aquatic herbicide applications. One possible mitigation measure would be not allowing applications if large populations of birds use shorelines or islands in the water body to be treated for nesting until after nesting is complete. Another mitigation measure would be to time applications to avoid migratory waterfowl and other bird species that use certain water bodies during migration. Efforts to avoid effects on migratory and nesting birds would best be coordinated between the permit writer and The Washington State Department of Fish and Wildlife (WDFW) prior to granting the permit. (Appendix C, Vol. 3, Sect. 4, p. 99).
Recommended Mitigation WDFW will review for timing with respect to nesting birds and migratory waterfowl.

Mammals Acute oral data are available for more than one mammalian species. These data indicate that 2,4-D BEE is slightly toxic and that 2,4-D acid is moderately to slightly toxic. Subchronic and chronic effects indicate that terrestrial species may be affected by long term exposure to 2,4-D acid in the diet. There are two common routes of exposure of livestock and terrestrial wildlife to aquatic applications of 2,4-D products. The two routes are exposure through drinking water treated with products containing 2,4-D or eating aquatic plants, fish or other aquatic organisms from the treatment site. Based on the acute and chronic studies listed above 2,4-D BEE and its breakdown product 2,4-D acid (used as an aquatic herbicide) do not pose a significant acute or chronic risk to terrestrial birds or mammals. However, in order to mitigate possible problems with the watering of dairy animals, the labels for these products do not allow applications to water bodies that are used for this purpose. The best mitigation or control for wild animals and birds is to follow the label directions. Many studies have been run on these products to ensure their safety to wildlife and the label directions and warnings reflect the results of these studies.

Therefore, if the chemicals are applied according to the label, the effect on terrestrial wildlife should be minimal (Appendix C, Vol. 3, Sect. 4, p. 100).
Recommended Mitigation Applications should be made by subsurface injection whenever practicable to avoid airborne drift. Repeat treatments should be minimized by use of appropriate follow-up management methods to herbicide applications.

Endangered Species WDFW recommends that before any application, if there is a potential to impact state priority species, applicators call WDFW Priority Habitats and Species data request number, (360) 902-2543, or visit the agency's website: www.wa.gov/wdfw/hab/phspage.htm to verify no species of concern will be impacted by the proposed herbicide application.
Recommended Mitigation WDFW must sign off on the application prior to treatment. The project cannot move forward without WDFW approval.

Water, Land and Shoreline Use

Public Health Results indicate that 2,4-D should present little or no risk to the public from acute exposures via dermal contact with sediment, dermal contact with water, or ingestion of fish. Dermal contact with vegetation may present limited risk if it is contacted one hour after application. By 24 hours post-application non-carcinogenic risk is essentially nonexistent, as 2,4-D is unavailable for dermal uptake. Margins of safety for all acute exposure scenarios are greater than "100", implying that risk of systemic, teratogenic, or reproductive effects to humans is negligible.

Results of chronic exposure assessments indicate that human health should not be adversely impacted from chronic 2,4-D exposure via ingestion of fish, ingestion of surface water, incidental ingestion of sediments, dermal contact with sediments, or dermal contact with water (swimming). Hazard quotients for every exposure pathway and scenario are small (8E-10 to 3E-01). Hazard quotients are consistently higher (i.e., higher risk) for the irrigation ditch scenario.

The overview presented in this document concerning the toxicology and risk assessment of 2,4-D in its use as an aquatic herbicide indicates that use of the chemical in accordance with label directions is not expected to result in adverse health effects. A review of the acute, subchronic and chronic toxicology investigations demonstrate that 2,4-D acid, amine salts and esters have similar degrees of low systemic toxicity. The amine salts and esters are metabolized to the acid and undergo rapid excretion by the kidneys. 2,4-D does not accumulate in the organism or environment, however when the administered dose exceeds the threshold for normal renal function, a decrease in excretion occurs resulting in possible systemic poisoning. Findings from subchronic and chronic toxicology studies and genotoxicity testing do not implicate that 2,4-D is a carcinogen or developmental or reproductive toxin in laboratory animals. A review of the epidemiology studies and opinions from scientific review panels indicate that some of the investigations present inconsistent results, design flaws, and contain confounding variables, associations between NHL and 2,4-D exposure are weak and conclusions by the investigators are conflicting. Therefore, based on the weight-of-the-evidence, label directed use of 2,4-D for aquatic herbicide control poses little concern for causing adverse health effects to people.

Agriculture At typical use rate concentrations, irrigation or flooding of crops with water that has been treated with 2,4-D DMA damages some crops and non-target wild plants. Although early growth stage damage has been observed on many crops including sugar beets, soybeans, sweet corn, dwarf corn and cotton, no significant reductions in yield were seen at harvest for most crops. Residue levels that would interfere with the marketability of crops were not seen in various crops including potatoes, grain sorghum, Romaine lettuce, onions, sugar beets, soybeans, sweet corn or dwarf corn. 2,4-D will not bioaccumulate in crop plants or fish at levels that will interfere with their marketability or consumption (Appendix C, Vol. 3, Sect. 4, p. 43).

Pastureland flooded with water containing 2,4-D may lead to the destruction of various turf plants. In addition, sensitive crop plants like Mexican red beans, lentils, peas, grapes and tomatoes may be irreversibly damaged by the presence of 2,4-D in irrigation or floodwater. Other non-target plants may be adversely impacted (Appendix C, Vol. 3, Sect. 4, pp. 102 and 154).
Recommended Mitigation Conditions on the product label govern domestic uses of the product.

Reentry and Swimming Use of the chemical in accordance with label directions is not expected to result in adverse health effects. 2,4-D BEE granules contain concentrated (27%) 2,4-D that is adhered to clay. The granules are dropped over submerged plants where they release their concentrated material. 2,4-D residues in the water column and sediments rise over the first 24 hours until they reach the treatment concentrations of 1-2,mg/l (parts per million) recommended for selective control of water milfoil. After 24 hours the chance of a swimmer or wading child coming into direct contact with the more concentrated granule would be negligible.
Recommended Mitigation Dermal contact with vegetation may present limited risk up to one hour after application. By 24 hours, post-application non-carcinogenic risk is essentially nonexistent, as 2,4-D is unavailable for dermal uptake. For all permitted, aquatic applications of 2,4-D, a swimming advisory shall be posted advising swimmers to wait 24 hours before reentering directly treated areas to allow time for granules to disperse.

Fish Consumption Human health should not be adversely impacted from 2,4-D ingestion of fish.
Recommended Mitigation Label conditions apply.

Boating Applies to boaters in the area of treatment during the application.
Recommended Mitigation For sub-surface applications and applications where the risk of airborne drift does not exist, no special restrictions are recommended. For treatments where particles of the herbicide are airborne due to spraying or the use spreaders, boaters must be advised to stay out of the treatment area while the application is underway.

Data Gaps

- Very little information was found quantifying 2,4-D adsorption to sediments, which is part of the reason this has been identified as a data gap. Concentrations of active ingredient 2,4-D degradation are primarily caused by the action of sediment microorganisms. The overall pattern is that BEE is broken down in natural pond and lake systems in a few days, while the resulting acid is usually below detection levels (approximately 0.01 ppm) in treated area water within a month. In sediment, the acid may persist from a few weeks to as long as 3 months, with occasional instances of persistence from 6 to 9 months, though this is unusual. Liquid DMA formulations can be expected to result in higher initial water concentrations than granular formulations, since all of the 2,4-D is applied directly to the water. Granular formulations will generally yield higher sediment concentrations and longer persistence in or on sediments due to a prolonged release of 2,4-D from the granules. Granular formulations can therefore result in lower water concentrations that may persist somewhat longer than if liquid formulations are used. Both aquatic formulations being evaluated for use in freshwater in Washington State have the potential to adversely impact aquatic biota, benthic organisms in particular. The 2,4-D butoxyethyl ester (BEE) formulation is comparatively more toxic than 2,4-D dimethylamine salt (DMA) to aquatic biota as measured in the laboratory, even though this toxicity is apparently not realized during actual field use. The hydrolysis of 2,4-D BEE to 2,4-D acid in nature is probably a key factor responsible for this generally observed lack of environmental toxicity. However, use of either formulation will be conditioned to mitigate for possible adverse effects. DMA formulations of 2,4-D, when available will be used whenever possible rather than BEE formulations of 2,4-D. Applications will be limited to no more than 2/season and spaced not less than a month apart to allow benthic organisms to rebound. And only the lowest effective concentration will be allowed to prevent acute toxicity.

- Further investigations need to be conducted to determine which levels of 2,4-D are safe to sensitive, threatened and endangered species (particularly chinook salmon, cutthroat and sea-run trout). Additional studies, including seawater challenge tests emphasizing species indigenous to the Northwest should be conducted so that risk due to exposure can be managed more effectively. While chinook salmon and sea-run cutthroat are mentioned as of particular need for further investigations so should there be more studies on char (bull trout) and steelhead. Steelhead, on average, are particularly susceptible to stress during smoltification (a physiological change needed to leave freshwater and go into saltwater). Other information that is lacking is impacts to amphibians, reptiles and insects, particularly *Lepidoptera.*

4. Mitigation Summary for 2,4-D

All label restrictions and conditions apply. Spill response conditions found in the general conditions of the water quality permit must be applied in the event of a spill.

Conditions of Treatment	**2,4-D BEE formulations**	**2,4-D DMA formulations**	**Mitigation Recommendation**
Cool surface water temperatures	A major drop in degradation occurs at temperatures less than 7° C (~45°F)	A major drop in degradation occurs at temperatures less than 7° C (~45°F)	Avoid use when temperatures <7° C are expected on surface waters due to prolonged persistence in sediments and increased risk of exposure to aquatic biota.
Soft water conditions (15-20 mg/l as $CaCO_3$), more common in Western Washington lakes	2,4-D BEE formulations are more toxic to juvenile coho, pink salmon and rainbow trout in soft water.	Mitigation does not apply to DMA formulations	When available, use DMA formulations of 2,4-D. Treatment sites should be routinely tested for hardness prior to treatment with 2,4-D BEE formulations. A mitigation plan must be submitted prior to the application to lakes with soft water.
Repeat applications	Persistence may result in elevated concentrations of 2,4-D acid if repeat applications are made.	Persistence in sediment not likely when repeat applications are made.	Applications of 2,4-D BEE should be limited to 2/season for each site treated unless treatments follow a management plan that addresses persistence concerns.
Drift onto adjacent shorelines	Mitigation Applies	Mitigation Applies	Terrestrial species may be affected by long term exposure to 2,4-D acid in the diet. Applications should be made by subsurface injection whenever practicable to avoid drift. Repeat treatments should be minimized by follow-up management methods to herbicide applications.
Eutrophic conditions	Aids degradation	Aids degradation	None
Whole lake treatments (>50% of the lake) or when treatment is made to small lakes with outlets and secondary effects of those treatments, or for spot treatment applications near outlets.	Mitigation Applies	Mitigation Applies	Water mass movement and the specific water budget must be calculated to minimize the transport of herbicides off the targeted site. Flow rates at outlets must be monitored. If outflows of treated water are anticipated, outlets must be blocked until herbicide levels are ≤ the drinking water limit of 0.1mg/L. Note: wind and precipitation may increase normal outflow rates. Proposed whole lake treatments must have a plan to deal with secondary effects of plant die-off and increased levels of nutrients.

Wetlands	Mitigation Applies	Mitigation Applies	A mitigation plan shall be required for proposed mitigation projects. See p. 12.
Sensitive biota, including amphibians	Affects *Gammarus fasciatus, Gammarus lacustris*, brown shrimp, nymphal stoneflies, aquatic sowbug, chironomid midge, seed shrimp or glass shrimp	Affects glass shrimp and seed shrimp	When available, use DMA formulations of 2,4-D and use the lowest effective concentration. Apply 2,4-D BEE at concentrations ≤ 100lbs. /acre.
Anadromous fish in area and/or endangered or listed species	Do not use at concentrations higher than 100 lbs./acre.	Use the lowest effective concentration.	Avoid exposure to salmonid spawning and rearing areas. Use the lowest effective concentration. Apply BEE at concentrations ≤ 100lbs. /acre. If endangered species are present, WDFW must sign off on the application prior to treatment.
WDFW requirements for habitat conservation	Mitigation applies	Mitigation applies	Contiguous areas covering a minimum of 25 to 40 % of the vegetation shall be left intact in the littoral area. When treating large areas random strips or patches of aquatic vegetation must be left untreated for fish habitat use. At least 25 to 40% of the submerged vegetative cover must be retained for optimum cover and forage for fish and wildlife.
Native plants	May have small impact	May have small impact	Label restrictions apply.
"Sensitive" plants or candidate species under review for possible inclusion in the state list of endangered or threatened species occurring along the banks of waterways to be treated	Mitigation applies	Mitigation applies	The applicator should leave a protective buffer zone between the treated area and the species of concern.
Algae	May contribute to algae blooms.	May contribute to algae blooms.	Not recommended for use on algae. There is evidence that alga numbers increase when a water body is treated with 2,4-D DMA or 2,4-D acid for the control of Eurasian watermilfoil due to release of nitrogen and phosphate.
Human exposure, domestic and swimming	Mitigation applies	Mitigation applies	Conditions on the product label govern the domestic use of the product. However, due to risk of dermal contact, a swimming advisory shall be posted advising swimmers to wait 24 hours before reentering directly treated areas to allow time for granules to disperse.
Poor water circulation, the formation of a thermocline, or a population crash of a dense species.	The bottom of the lake (and possibly shallower depths) can become anaerobic, inhibiting degradation of the herbicide.	The bottom of the lake (and possibly shallower depths) can become anaerobic, inhibiting degradation of the herbicide.	Repeat treatments shall be limited on a case-by-case basis.
Detection of 2,4-D in groundwater	Mitigation applies	Mitigation applies	Groundwater must be tested prior to treatment. Washington groundwater limit for 2,4-D is 0.10 mg/l (Chapter 173-200 WAC). Groundwater cannot be re-exposed to 2,4-D without a plan protective of groundwater.

Drinking water withdrawals, irrigation.	Mitigation applies	Mitigation applies.	In addition to label restrictions, if water withdrawals exist within one-half mile of the proposed treatment area, an approved mitigation plan must be submitted prior to treatment. The plan must be in effect until herbicide levels are at or below the drinking water limit of 0.1 mg/L. Downstream irrigators must be notified to ensure they do not use 2,4-D treated water to irrigate 2,4-D sensitive plants for one week following treatment.
Application methods	Product labels specify application methods.	Product labels specify application methods.	No aerial applications permitted
Fish consumption	Does not apply	Does not apply	Human health should not be adversely impacted from chronic 2,4-D exposure via ingestion of fish. Label conditions apply.

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